A Model-Based Analysis of Anxiety and Biased Processing of Threatening Information

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Abstract

The present study employed a decision model to explore processing biases in anxiety. Anxious individuals show preferential attention to threatening compared to neutral information, which can serve to maintain or increase levels of anxiety. Several models of anxiety predict biased processing of threat under most circumstances, but previous research has failed to demonstrate a threat bias in certain tasks involving word recognition and memory. This has been taken by some researchers as evidence that the threat bias is dependent on contextual factors. An alternative explanation is that threat bias is present in these tasks, but analytical methods are not sensitive enough to detect small differences.

The present study was designed to determine if threat bias could be shown in word recognition and memory tasks. Individuals with high and low levels of anxiety were compared in their responses to threatening words. Behavioral data were analyzed with the diffusion model, a quantitative model of decision processes that provides a more sensitive measure of processing than traditional measures, response times and accuracy. The diffusion model analysis showed that the high-anxiety participants had consistent advantages for early processing of threatening words, but disadvantages for later memory of threatening words. The results from these experiments are consistent with several models of anxiety, with anxious individuals showing initial vigilance in the detection of threat, but avoidance of deeper processing of threatening

information. The improved sensitivity of the model-based analysis suggests that previous failures to show threat bias might have been due to use of imprecise dependent measures. By demonstrating threat bias in these tasks, there is no longer a need for *ad hoc* explanations of why the bias does not occur in certain conditions, allowing for more parsimonious models of anxiety.

Introduction

There has been great interest in the manner in which high levels of anxiety affect information processing. In particular, many researchers have focused on how anxious individuals process threatening information differently than non-anxious. In this context, threatening information refers to both physical threat, like the words *cancer* or *death*, and social threat, like the words *failure* or *embarrassment*. There is robust evidence that anxious individuals show preferential attention to threat, whereas non-anxious individuals do not (for a review, see Mogg & Bradley, 2005). For example, suppose that two words, *cancer* and *jacket,* are flashed briefly in different locations on a screen. In such situations, anxious individuals will preferentially attend to the threatening word over the neutral one (e.g., Bradley, Mogg, Falla, & Hamilton, 1998). Similar effects have been demonstrated across a range of experimental paradigms, supporting the claim that anxious individuals have an attentional bias for threat. This attentional bias can result in serious consequences. Because anxious individuals are more vigilant for threat, they tend to detect and experience more threat than non-anxious individuals.

This, in turn, can serve to maintain or increase anxious states, and in some cases lead to clinical anxiety disorders (Eysenck, 1992; Mathews, 1990). Thus this early attentional bias is an important component of anxiety.

While there is strong evidence for early vigilance for threat in anxious individuals, research on memory for threat provides evidence for later avoidance of threat. Although overall evidence for anxiety-related differences in memory for threat is mixed (Mitte, 2008), several studies suggest that anxious individuals might have weaker memory for threatening information. For example, when asked to recall as many studied words possible, anxious individuals have been shown to recall *fewer* threat words than neutral ones (Wenzel & Holt, 2002). This might seem counterintuitive. Since these individuals show enhanced early processing of threat, it is reasonable to expect that they would have better memory for threat as well. The fact that they tend to have poorer memory for threat suggests that they avoid the deeper processing required to form strong memories. Consistent with this explanation, avoidance of threat is a central component of anxiety disorders and can lead to severe impairments (see Borkovec & Roemer, 1995).

Thus there is evidence that anxious individuals show early vigilance for threat, but later avoidance of it. A clear understanding of these components of anxiety is important for both prevention and treatment of anxiety disorders. The present study investigates an unresolved issue in this domain: vigilance-avoidance behavior is found in some circumstances but not others. The focus is on two experimental paradigms, lexical decision and recognition memory, that should reveal vigilance-avoidance behavior, but typically do not.

In lexical decision, participants are shown strings of letters and must decide for each one if it is a word or not. For anxious individuals, threat vigilance should produce a benefit for identifying threat words compared to neutral words. However, several studies have failed to demonstrate such an effect (Hill & Kemp-Wheeler, 1989; Mathews & Milroy, 1994; Mogg, Mathews, Esyenck, & May, 1991), prompting some researchers to conclude that the attentional bias to threat only occurs when multiple items compete for attention (McCleod & Mathews, 1991). Since the lexical decision task involves only one item presented at a time, there is no competition for attention and thus no threat vigilance for anxious individuals.

In recognition memory, participants study a list of words, and are shown a new list and must decide for each word if it was studied or not. This task rarely shows differences between anxious and non-anxious in memory for threat words (for a meta-analytic review, see Mitte, 2008). This lack of memory differences suggests that threat avoidance does not affect recognition processes, whereas it does affect the processes involved in recalling threat words from memory.

The failure to show vigilance-avoidance behavior in lexical decision and recognition memory suggests that anxiety-related biases in threat processing only manifest under certain circumstances. The goal of this study was to explore an alternative explanation, namely that there are small effects in lexical decision and recognition memory tasks, but traditional dependent measures are not sensitive enough to detect them. A quantitative model of decision making was used to provide a more sensitive measure and test this hypothesis. If anxiety-related biases for threat are found with a model-based analysis, then the vigilance-avoidance pattern of behavior should be considered a general phenomenon that is not restricted to certain circumstances or processes. The decision model is briefly introduced in the next section.

Insensitive Measures and the Diffusion Model

Recognition memory and lexical decision are two-choice tasks in which both the accuracy and speed of the decision are recorded. Traditional analyses are based on the assumption that stimuli that provide strong evidence will lead to fast and accurate responses. In lexical decision, RTs and accuracy reflect how easily the letter string is identified as a word or nonword. In recognition memory, these measures reflect how easily the word is recognized as studied or unstudied. Thus RTs and accuracy are used to index the strength of evidence a stimulus or class of stimuli provide for a decision. Unfortunately, both measures are affected by factors other than evidence strength. For example, some participants respond cautiously, which leads to slow RTs but high accuracy, whereas others respond liberally, which leads to faster RTs but lower accuracy. This difference in response style is independent of the stimulus evidence, yet it still affects the measures used to index stimulus evidence. In this manner, RTs and accuracy are imprecise measures of evidence strength. Decison components like response caution essentially add noise to the RTs and accuracy, which decreases their sensitivity (White, Ratcliff, Vasey, & McKoon, submitted). Accordingly, RTs and accuracy are not optimal measures to detect small differences in evidence strength.

The diffusion model (Ratcliff, 1978, Ratcliff & Smith, 2004) provides a promising alternative to analyses of RTs and/or accuracy. The diffusion model is a formal model of the processes involved in fast, two-choice decisions. A schematic of the model is shown in Figure 1. Figure 1A shows the whole process for the response and Figure 1B shows just the decision component. In the model, noisy evidence is accumulated over time for one response or the other. The process starts at some point, *z*, and proceeds until it reaches a boundary (*a* or *0* in Figure 1B). There is noise in the accumulation process, represented by the two, nonmonotonic sample paths in Figure 1B. Because evidence accumulation is noisy, responses with the same drift rate terminate at different times, producing RT distributions. Further, sometimes the noise drives the process to the wrong boundary, producing errors.

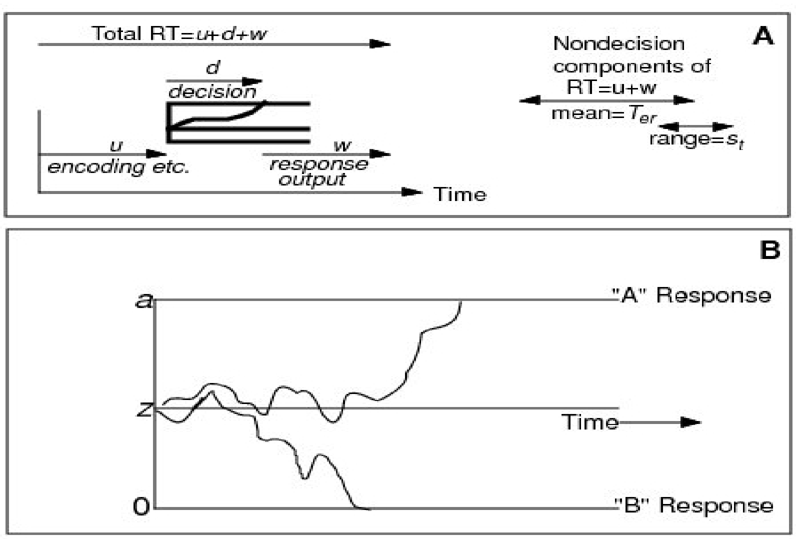

Figure 1. Schematic of the diffusion model. See text for details.

There are four primary components to the model, each with a straightforward psychological interpretation. The nondecision component indexes the amount of time taken for processes outside the decision process, like visual encoding and response output (e.g. pressing the button). The drift rate, v, is the average rate of approach to a boundary, and indexes the quality of evidence from the stimulus. A high drift rate will reach the correct boundary quickly, leading to fast and accurate responses. A low drift rate will take longer to reach the boundary, and is more likely to hit the wrong boundary due to noise in the accumulation process, leading to slower and less accurate response. The distance between the two boundaries indexes a participant's caution or speed/accuracy settings. If the boundaries are far apart, responses will take longer to reach the boundary, but are less likely to cross the wrong boundary, leading to slow but accurate responses. If the boundaries are close together, RTs will be fast, but accuracy will be lower due to many processes hitting the wrong boundary. The starting point, z, indexes bias for a response. If the process starts closer to the boundary A, those responses will be faster and more probable than responses corresponding to boundary B.

The diffusion model is fit to behavioral data, producing estimates for each of the decision components. The most relevant component for this study is drift rate. Because the model identifies the contribution of the other aspects of the decision process, these extraneous factors do not affect drift rates, so they more accurately reflect stimulus evidence compared to RTs or accuracy. Thus smaller effects can be detected by using the model, allowing a better assessment of vigilance-avoidance in lexical decision and recognition memory tasks.

Experiments

Five experiments were performed to determine if biased processing of threat could be demonstrated in lexical decision and recognition memory tasks. Each finding was replicated with at least one separate group of participants to ensure robust results. For each experiment, undergraduate participants were divided into low- and high-anxiety based on their scores on the Speilberger Trait Anxiety Inventory (Spielberger, Gorsuch, & Lushene, 1970), a self-report anxiety questionnaire. There were approximately 21 participants in each group for every experiment.

The experiments were designed to allow comparison of threat words and nonthreat words that were matched on characteristics known to affect responses (e.g., word frequency; Mathews, Mogg, May, & Eysenck, 1989). To ensure that they were not identified as stimuli of interest, the threat and nonthreat words were presented sporadically among many other filler items. In the lexical decision experiments, strings of letters were shown and participants decided if each was a word or not. In the recognition memory experiments, a list of words was studied, then participants had to decide for each test word if it had been on the study list or not.

The diffusion model was fit to each participant's data. The model takes both accuracy values and the distribution of RTs for each condition to estimate values for components of the decision process. Thus each person had a value for evidence quality (drift rate), response caution (boundary separation), response bias (starting point), and nondecision time. These values could then be submitted to statistical testing in the same manner as RTs and accuracy.

Results. Results from the experiments are presented as threat bias (Figure 2), which is calculated as the difference between threat and nonthreat words (complete data is presented in the appendix). A positive value of threat bias indicates an advantage for threat words (i.e., easier to identify in lexical decision, easier to remember in recognition memory), whereas a negative value indicates a disadvantage. Threat bias was calculated for each measure of evidence quality:

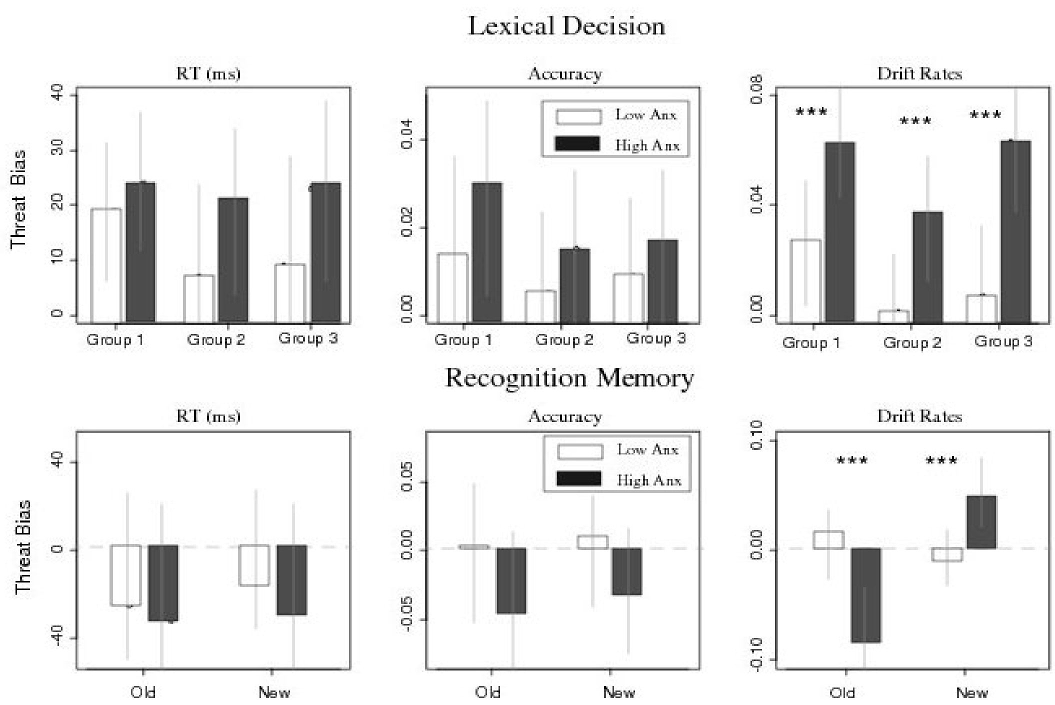

Figure 2. Plot of threat bias for lexical decision and recognition memory. For lexical decision, larger threat bias indicates greater advantage for threat words. For recognition memory, negative threat bias indicates disadvantage at recognizing threat words. Error bars are 2 SEs; *** indicates significant difference between high- and low-anx (p < .05).

RTs, accuracy, and drift rates. For each set of participants, an Analysis of Variance (ANOVA) was used to determine whether threat bias differed between high- and low-anxiety participants. There were three separate groups for lexical decision. For recognition memory, threat and matched nonthreat words were studied for one group (old) and unstudied lures for another (new).

For lexical decision, RTs and accuracy showed a trend for a larger threat bias in the high-anxiety groups, but the differences were not significant. Drift rate comparisons, on the other hand, showed a consistent threat bias that was significantly higher for the high-anxiety groups. For recognition memory, there were no effects in RTs. Accuracy and drift rates showed a similar pattern, though the differences were only significant for drift rates: high-anxiety participants were worse at correctly recognizing threat words that had been studied (old), but better at correctly rejecting threat words that had not been studied (new). In other words, high-anxiety participants were less likely to indicate that they had studied the threat words, regardless of whether or not they appeared on the study list.

Because the drift rates extracted by the diffusion model were more sensitive to processing differences, they were able to reveal consistent threat biases in high-anxiety participants that were not apparent with comparisons of accuracy or RTs. The model also allows comparison of the other decision components that index response caution, nondecision time, and response bias (see Appendix). In short, none of these components differed between high- and low-anxiety participants.

Discussion

The present study demonstrates anxiety-related threat biases in lexical decision and recognition memory. Consistent with previous studies, comparisons of RTs and accuracy did not show significant differences between high- and low-anxiety participants, though there were nonsignificant trends in the expected direction. However, the more sensitive measure provided by the diffusion model showed consistent effects that replicated with separate samples. Anxious participants had an advantage for threat words in the lexical decision task, which is consistent with early vigilance in the detection and identification of threatening information. They also showed evidence of weaker memory for threat words, which is consistent with avoidance of deep processing of threatening information.

By demonstrating biased processing of threat in lexical decision and recognition memory tasks, the present study shows that anxiety-related biases in threat processing are more general and pervasive than previously thought. As such, these two components of anxiety should be addressed when assessing potential therapies for anxiety disorders. Additionally, the results from the present study allow for more parsimonious models of anxiety, in that there is no longer a need for *ad hoc* accounts of why threat bias does not manifest in these tasks.

The diffusion model proved to be a valuable asset for data analysis in this study, and it is recommended that future research involving two-choice tasks consider the model as an alternative to comparisons of RTs and accuracy. Quantitative models like the diffusion model can improve analyses of behavioral data by explicitly formulating the relationship between the data and the underlying processes. Null results should be interpreted cautiously as they might reflect an underpowered design or insensitive analytical methods rather than a true lack of differences. The diffusion model provides a practical approach to increase sensitivity without needing to add subjects, making it a promising analytical tool for future explorations of processing differences associated with anxiety.

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Table 1. Response times, accuracy, and drift rates averaged across participants

	Low Anx			High Anx		
Lexical Decision	Accuracy	Mean correct RT	Drift Rates	Accuracy	Mean correct RT	Drift Rates
Group 1						
Threat	.924 (.03)	654 (232)	.277 (.10)	.935 (.03)	675 (240)	.331 (.10)
Nonthreat	.911 (.03)	673 (258)	.254 (.08)	.908 (.04)	699 (280)	.267 (.07)
Group 2						
Threat	.891 (.03)	693 (268)	.262 (.08)	.915 (.03)	691 (261)	.259 (.08)
Nonthreat	.886 (.04)	700 (274)	.263 (.08)	.900 (.03)	711 (280)	.225 (.06)
Group 3						
Threat	.946 (.03)	681 (240)	.309 (.11)	.925 (.04)	678 (240)	.324 (.10)
Nonthreat	.937 (.03)	690 (235)	.302 (.11)	.909 (.05)	701 (265)	.261 (.07)
Recognition Memory						
Studied						
Threat	.744 (.09)	721 (257)	.164 (.07)	.770 (.08)	740 (243)	.137 (.12)
Nonthreat	.742 (.08)	696 (197)	.165 (.07)	.812 (.07)	718 (234)	.213 (.13)
Unstudied						
Threat	.729 (.09)	791 (275)	.158 (.12)	.757 (.07)	833 (296)	.199 (.08)
Nonthreat	.722 (.10)	776 (233)	.176 (.13)	.728 (.09)	805 (270	.158 (.10)

Note. SDs are shown in parenthesis. Groups 1, 2, and 3 refer to separate groups of participants. RT = response times.

Table 2. Decision components from the diffusion model averaged across subjects

Lexical Decision	Boundary Separation	Nondecision Time	Response Bias
Group 1			
Low Anxiety	.137 (.02)	.437 (.04)	.501 (.02)
High Anxiety	.148 (.02)	.448 (.04)	.500 (.01)
Group 2			
Low Anxiety	.137 (.03)	.444 (.03)	.507 (.03)
High Anxiety	.140 (.03)	.442 (.04)	.468(.04)
Group 3			
Low Anxiety	.131 (.02)	.446 (.04)	.504 (.02)
High Anxiety	.132 (.03)	.451 (.03)	.498 (.02)
Recognition Memory			
Group 1 (studied)			
Low Anxiety	.125 (.03)	.513 (.06)	.482 (.02)
High Anxiety	.127 (.02)	.515 (.04)	.465 (.03)
Group 2 (unstudied)			
Low Anxiety	.125 (.03)	.521 (.05)	.467 (.02)
High Anxiety	.136 (.03)	.540 (.05)	.455 (.02)

Note. SDs are shown in parenthesis. Groups 1, 2, and 3 refer to separate groups of participants for the lexical decision task. For the recognition memory task, threat and nonthreat words were presented as studied for one group, and unstudied for another. Response bias is calculated as the starting point divided by boundary separation. Values of bias less than .5 indicate a bias towards the word response in lexical decision and the old (studied) response in recognition memory.